CONCERT-Japan

Efficient Energy Storage and Distribution

"Novel carbon-free cathode materials for metal-air rechargeable batteries"

CarFree

INTERIM REPORT

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Metal–air secondary batteries, consisting of a metal anode and an air carbon-based cathode, have been suggested for large-scale storage of electric power because of a very high theoretical energy density. In this project, novel electrode materials for both Lithium–oxygen (Li-O_2) batteries with non-aqueous electrolyte and Zn-air batteries with aqueous alkaline solution are being developed.

However, carbon-based air-electrodes decompose at potentials above 3.5 V vs Li/Li^+ in the presence of Li_2O_2 and its intermediates formed during charge-discharge reactions, producing poor cyclability and coulombic efficiency with large overpotential. Consequently, the project is aim to explore the feasibility of different synthesis routes to develop novel carbon-free cathode electrode materials for Li-O_2 and Zn-air batteries. These new air-electrodes are based on Ti, Mo, Fe, Zr, Ta, Mn (oxides, carbides, nitrides, and combination of them) inserted in a macro-mesoporous interconnected structure. At the same time, stable liquid and polymer electrolytes using different solvents, Li salts, organic additives and ceramic fillers are being developed to use in combination with the new carbon-free cathode materials.

A key step in this project is the understanding of the basic ORR and OER mechanisms with these new materials to gain new knowledge of the physics behind performance and outline potentialities of the materials using kinetic Monte Carlo simulations, Density Functional Theory and Continuum modeling.

Different approaches in the synthesis of the new materials for air electrodes are being evaluated, including synthesis of macro-mesoporous particles, core-shell particles, infiltration/ coating of nickel foam, high temperature heat treatments in controlled atmosphere, synthesis of Layered Double Hydroxide (LDH) Nanocomposites, nitrogen incorporation using urea, porosity generation by incorporating viruses, etc.

Likewise, work is devoted on the method of characterizing the oxygen reduction reaction (ORR) and oxygen evolution reaction (OER), since commercial rotatory electrodes are made of carbon, an element that is intended to be eliminated from the air cathode composition.

On the other hand, a high percentage of effort is being focused to electrochemical characterization in half cell and full cell for metal-O2/air batteries, since commercial cell prototypes are scarce and inefficient so far.